Jurnal Biosains Pascasarjana Vol. 27 (2025) 18-24

ANTI-INFLAMMATORY POTENTIAL OF FUNGUS COMBS FROM INDO-MALAYAN TERMITE MACROTERMES GILVUS HAGEN MOUND: REVIEW ARTICLE

Retno Pudji Rahayu [1,2], Sri Wigati Mardi Mulyani [1,3], Ristya Sylva Imannia [4], Jefferson Caesario [4], Dyta Loverita [5], Elvin Nuzulistina [6]

[1]Lecturer of Immunology, Postgraduate School, Universitas Airlangga, Surabaya, 60115, East Java, Indonesia
[2]Lecturer of Oral & Maxillofacial Pathology Department, Faculty of Dentistry, Universitas Airlangga, Surabaya, 60115, East Java, Indonesia
[3] Lecturer of Innovation, Regenerative Medicine and Stem Cells in Oral & Maxillofacial Radiology Department, Faculty of Dentistry, Universitas Airlangga, Surabaya, 60115, East Java, Indonesia
[4] Graduate Student of Immunology, Postgraduate School, Universitas Airlangga, Surabaya, 60115, East Java, Indonesia
[5] Lecturer of Obstetrics-Gynecology Department, Faculty of Medicine, Universitas Negeri Malang, Malang, 65145, East Java, Indonesia
[6] Medical Doctor, Universitas Airlangga, Surabaya, 60115, East Java, Indonesia
*E-mail: ristyasylva@gmail.com

Abstract

There is evidence that termite colonies of the subfamily Termitomyces produce an unusual structure called a fungus comb, especially Termite mounds in Indo-Malaysian regions. This comb may include bioactive components that the termites use to investigate if they might aid in the body's inflammatory response. The anti-inflammatory potential, concentration, and bioavailability of fungal comb from the Indo-Malayan termite macrotermes gilvus Hagen mound will be further discussed in this research. We utilized databases to review the current evidence related to anti-inflammatory potential of fungus combs and termite macrotermes gilvus hagen mound. We discussed the most recent evidence of fungus combs and termite macrotermes gilvus mound regarding the anti-inflammatory potential, concentration, and bioavailability. This study concludes that ethyl acetate extract from fungus comb could enhance the immune system. Phenolic compounds have a positive effect on health indicators. These mechanisms may account for the decreased prevalence of chronic degenerative disorders in populations.

Keywords: Anti-inflammatory, fungus-combs, termites hagen mound sp.

Abstrak

Ada bukti bahwa koloni rayap dari subfamili Termitomyces menghasilkan struktur yang tidak biasa yang disebut sisir jamur, terutama gundukan rayap di wilayah Indo-Malaysia. Sisir ini mungkin mengandung komponen bioaktif yang digunakan rayap untuk menyelidiki apakah komponen tersebut dapat membantu respons peradangan tubuh. Potensi anti-inflamasi, konsentrasi, dan bioavailabilitas sisir jamur dari gundukan rayap Indo-Malaysia macrotermes gilvus Hagen akan dibahas lebih lanjut dalam penelitian ini. Kami memanfaatkan basis data untuk meninjau bukti terkini yang terkait dengan potensi anti-inflamasi sisir jamur dan gundukan rayap macrotermes gilvus hagen. Kami membahas bukti terbaru dari sisir jamur dan gundukan rayap macrotermes gilvus mengenai potensi anti-inflamasi, konsentrasi, dan bioavailabilitas. Ekstrak etil asetat dari sisir jamur dapat meningkatkan sistem kekebalan tubuh. Senyawa fenolik memiliki efek positif pada indikator kesehatan. Mekanisme ini dapat menjelaskan penurunan prevalensi gangguan degeneratif kronis pada populasi.

Kata Kunci: Antiinflamasi, sisir jamur, rayap hagen mound sp.

1. INTRODUCTION

Because of its tropical climate, Indonesia is home to several different kinds of termites. There are 3,106 species of termites known to science, with 300 (11.5%) of them species residing in Indonesia. Among the termite species found in Indonesia, the Indo-Malaysian Macrotermes gilvus Hagen (Isoptera: Termitidae) has the greatest distribution under these circumstances. Almost every region in the nation has received reports of this termite species. This species of termite builds its colonies in elaborate tunnel networks resembling nests. In the event of very harsh weather, it will shield the colony from harm. Termites gather nourishment for their colonies by building fungal ridges or gardens in their nests. The termite is known as the fungus-growing termite because it shares this trait with other termites in the subfamily Macrotermitinae (Njouonkou et al., 2020; Omonike et al., 2021; Al-Faqeeh et al., 2020; Mahamat et al., 2018; Nandika et al., 2021). Consequently, the anti-inflammatory potential, concentration, and bioavailability of fungal comb from the Indo-Malayan termite macrotermes gilvus Hagen mound will be further discussed in this research.

2. METHODS

This study is a review article conducted in July, 2024. The search was conducted using Scopus, Pubmed, and Sage Journal databases from 2015 to 2024. The following search pattern was applied: (Termite Macrotermes Gilvus Hagen Mound OR Fungus Comb), (Termite Macrotermes Gilvus Hagen Mound OR Fungus Combs AND Bioactivity), and (Termite Macrotermes Gilvus Hagen Mound OR Fungus Combs AND Anti-inflamatory). Results from search include national and international articles in English language and are full-text articles. References of retrieved articles were hand searched. Articles published as international articles in English languages. Titles and abstracts of papers were screened. Relevant papers were selected and duplicates were removed. We discussed the most recent evidence of fungus combs and termite macrotermes gilvus mound regarding the anti-inflammatory potential, concentration, and bioavailability.

3. RESULTS AND DISCUSSION

3.1 Fungus Combs From Indo-Malayan Termite Macrotermes Gilvus Hagen Mound

In their nests of Termitomyces sp., termite colonies of the subfamily Macrotermitinae (Isoptera: Termitidae) create a unique structure called fungus comb, which serves as a substrate for the fungus. The structure in question resembles a mammalian brain and has a volume of 44.17 ± 7.36 cm, with chambers that are linked from the top to the bottom. There are two sections to the fungal comb. You can see the old comb at the bottom and the new comb on top. An important component of the fungus-comb structure is the increased density of older combs compared to younger ones. The fungal comb maintains a constant temperature throughout the year because to its well-ventilated and tunnel-connected structure, which enables carbon dioxide to be exchanged with the surrounding environment. Macrotermitinae colonies rely on Termytomyces nodules, which are produced by the fungal mycelium that develops inside these fungus combs. Asexual nodules include a spherocyst, a conidium, and a cluster of short-celled hyphae. The inability to produce a fungal comb is a certain way for a termite colony to perish from lack of food. Termites feed on Termitomyces nodules, thus the fungus doesn't always make fruiting bodies (Katariya et al., 2017; Sharma et al., 2022, Mahamat et al., 2018a; Mahamat et al., 2018b).

Termites, which are members of the order Isoptera, are gregarious insects that feed on cellulose and reside in colonies. In spite of their common name, termites are really more closely linked to cockroaches than ants, according to evolutionary research. The termite fauna of Indonesia is very diverse, with 300 different species found throughout the country. Different kinds of termites may thrive on about 80% of Indonesia's territory. When it comes to nesting and feeding, termites of the subfamily Macrotermitinae (Isoptera: Termitidae) are unlike any other. Its nests may be as tall as three meters and can take the shape of little mounds. In their underground homes, termites construct a fungal comb, an unusual structure that resembles the brain of a mammalian.[9]

Termite monocultures thrive in fungal comb, which provides a food supply in the form of nodules. Fungus combs and Termitomyces nodules have physiologically active inflammatory material that may hinder the development of other microorganisms, which is believed to be associated with this disorder. So, it's fascinating and important to study fungal comb for its bioactive components. In 2021, Nandika et al. documented the chemical composition of fungal comb and found that it significantly inhibited the development of Aspergillus foetidus, a wood colouring fungus. Bioactive components derived from mushroom combs were investigated for their anti-inflammatory potential in a recent research. This termite species' anti-inflammatory characteristics became the centre of attention in pharmaceutical investigations (Witasari et al., 2022; Meneses et al., 2018).

3.2 Fungus Comb and Its Bioactivity Potential

A GC-MS analysis of the fungal comb yielded two distinct extracts: one in n-hexane and one in ethyl acetate. Given that the chemicals in question are quite volatile, GC-MS was used for the extraction procedure. However, as these chemicals are not easily vaporised, LC-MS would be the superior method for analysing the water and methanol extracts. Table 1 shows that there were 18 different kinds of chemicals detected in the n-hexane extract, with six of them being dominating compounds. The extract included more non-polar molecules (Nandika et al., 2021).

Table 1. Dominant compounds in fungus comb n-hexane extract and their potential bioactivity (Nandika et al., 2021; Krishnamoorty & Paulsamy, 2014; Devi & Muthu, 2014; Lima et al. 2011; Suryaningrum et al., 2006)

Compounds*	Relative concentration (%)	Bioactivity Potential
Bis (2-ethylhexyl) phthalate	69.43	Antibacterial and antimicrobial
Methyl palmitate	4.55	Anticancer, antibacterial, and antifungal
Methyl oleate	4.17	Anticancer and insecticide
Methyl linolelaidate	2.03	Antihistamine and antibacteria
1,2,3-*trimethyl-benzene*	1.61	Antioxidant
Benzenepropanoic acid, 3,5-*bis(*1,1 *dimethylethyl)*-4-*hydroxy-, methyl ester*	1.16	Antifungal dan antioxidant

According to a study conducted by Nandika et al., the compound with the highest relative concentration was bis(2-ethylhexyl) phthalate (69.43%) (Nandika et al., 2021). It was found that this chemical exhibited bioactivity against bacteria and other microbes. More specifically, the n-hexane fungal comb extract contains a number of fatty acid derivatives, including methyl ester, benzenepropanoic acid 3,5-bis(1,1 dimethylethyl)-4-hydroxy-, methyl oleate, methyl linolelaidate, and benzenepropanoic acid. The Solena amplexicaulis plant also contains other chemicals with bioactive anticancer, antibacterial, and antifungal properties, such as methyl palmitate and methyl oleate (Krishnamoorty & Paulsamy, 2014).

Research conducted by Devi et al revealed that a methyl linoleate compound was isolated from the ethanol extract of the Saccharum spontaneum plant which has bioactivity as an antihistamine. This statement was also supported by Lima et al who also added that the compound isolated from Annona cornifolia seed extract had bioactivity as an antibacterial and antihistamine (Devi & Muthu, 2014; Lima et al. 2011).

According to Suryaningrum et al, the 1,2,3-trimethyl-benzene compound isolated from Halymenia harveyan seaweed has bioactivity as an antioxidant (Suryaningrum et al., 2006). Bashir et al. (2012) did more research on the benzenepropanoic acid 3,5-bis(1,1 dimethylethyl)-4-hydroxy- and methyl ester. These molecules exhibited antioxidant and antifungal bioactivity, according to the study's conclusions (Bashir et al., 2012.

The ethyl acetate extract of fungal comb, on the other hand, often contains chemicals that are phenolic groups. Table 2 shows that out of the fourteen kinds of chemicals identified by GC-MS analysis of the fungal comb's ethyl acetate fraction, four were the most abundant.

Table 2. Dominant compounds in ethyl acetate extract of fungus comb and their potential bioactivity (Nandika et al., 2021; Rawal & Sonawani, 2016; Velmurugan et al., 2009; Oramahi et al., 2011; Cicerale et al., 2012)

Compounds*	Relative concentration (%)	Bioactivity Potential
1,2,3-*propanetriol*	28.93	Antimicrobial
Phenol. 2-methoxy-	8.45	Antifungal, antiinflammation, antimicrobial, and antioxidant
Phenol. 2,6-dimethoxy-	6.55	Antifungal, antiinflammation, antimicrobial, and antioxidant
Bis (2-ethylhexyl) phthalate	4.82	Antibacterial and antimicrobial
1,2,3-*propanetriol*	28.93	Antimicrobial

Glycerol, or 1,2,3-propanetriol, is the most abundant component in the ethyl acetate extract of fungal comb. An antibacterial effect of this chemical has been previously shown.[16] Other compounds include phenol, 2-methoxy- and phenol, 2,6-dimethoxy-. Research conducted by Velmurugan et al and Omarahi et al revealed that two compounds isolated from Pinus densiflora and Quercus serrata extracts had antifungal activity. Besides that, these two compounds had also been defined as having anti-inflammatory, antimicrobial, and antioxidant effects according to research conducted by Cicerale et al (Velmurugan et al., 2009; Oramahi et al., 2011; Cicerale et al., 2012). The compound Bis(2-ethylhexyl) phthalate in ethyl acetate extract can have bioactivity as an antibacterial and antimicrobial according to research conducted by Nandhika et al as shown in Figure 1 (Nandika et al., 2021).

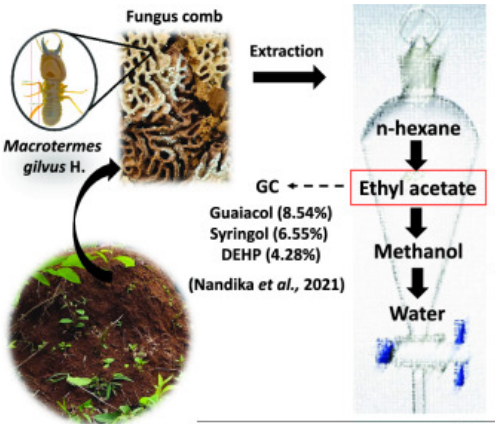

Figure 1. The fungus comb extraction process used GC-MS and obtained two extracts namely n-hexane and ethyl acetate (Nandika et al., 2021)

3.3 Anti-Inflammatory Properties of Ethyl Acetate Extract From Fungus Comb Compounds

It is no secret that chronic inflammation plays a role in the pathogenesis of many prevalent illnesses. This includes cancer, heart disease, arthritis, and neurological disorders. Some of the chemicals found in the ethyl acetate extract of fungal comb include phenol, 2,6-dimethoxy-, 1,2,3-propanetriol (glycerol), and 2-methoxy-dan-phenol. The anti-inflammatory properties of phenolic compounds have been shown in previous research. Researchers have demonstrated that phenolic compounds may lower the body's inflammatory response and the risk of acquiring chronic inflammatory illnesses in both in vivo and in vitro tests (Corona et al., 2009; Konstantinidou et al., 2010; Khymenets et al., 2009).

These findings have crucial health implications since monocytes and these chemicals are involved in the development of inflammatory diseases, and recent in vitro investigations have shown that phenol suppresses TNFα-induced matrix metalloproteinase 9 (MMP-9) in a monocyte cell line (Dell'Agli et al., 2010). Another interesting finding is that the phenolic molecule and the non-steroidal anti-inflammatory medication ibuprofen have the same anti-inflammatory route [24]. Compared to ibuprofen at equimolar concentrations, the phenolic compound inhibits the inflammatory enzymes cyclooxygenase-1 (COX-1) and

cyclooxygenase-2 (COX-2) in a dose-dependent manner in vitro (Beauchamp et al., 2005). Inducible nitric oxide synthase (iNOS) is an inflammatory mediator that contributes to the pathophysiology of osteoarthritis; recent research have shown that phenolic compounds may suppress this enzyme and other inflammatory mediators (Iacono et al., 2010). Because of its anti-inflammatory and neuroprotective effects, the phenolic molecule has garnered interest as a possible pharmacological agent for the treatment of neurodegenerative illnesses, such as Alzheimer's (Pitt et al., 2009; Li et al., 2009). Phenolic compounds have also been shown to have anti-proliferative effects on human breast and prostate cancer lines (Elnagar et al., 2011). In HT-29 cells originating from human colon adenocarcinoma, the phenolic compound increased cell death in addition to its antiproliferative activities by activating caspase-3 and polyadenosine diphosphate ribose polymerase, p53 (Ser15) activation, and generating DNA fragmentation.

In animal models of inflammation, phenolic compounds significantly reduce inflammation and reduce levels of proinflammatory cytokines including TNFα and interleukin-1 beta (IL-1β), which are frequent in inflammatory illnesses (Gong et al., 2009). In a mouse model of inflammation that was loaded with carrageenan, Impelliseri et al. discovered that phenol reduced the inflammatory response (Impellizzeri et al., 2011).

4. CONCLUSIONS

Previous studies in an inflamed mouse model have shown that ethyl acetate extract from fungus comb could enhance the immune system. Ethyl acetate extract of acetate fungus comb has some compounds which include 1,2,3-propanetriol (glycerol), phenol, 2-methoxy- dan phenol, 2,6-dimethoxy-. Many investigations, both in living organisms and in controlled laboratory settings, have shown that phenolic compounds have anti-inflammatory properties. This paper outlines the mechanisms by which phenolic compounds have a positive effect on health indicators; these mechanisms may account for the decreased prevalence of chronic degenerative disorders in populations.

REFERENCES

Al-Faqeeh, L. A. S., Naser, R., Kagne, S. R., & Khan, S. W. (2020). Nutritional values, ethnomedicinal uses and antioxidant activity of mushroom: A review. *European Journal of Biomedical and Pharmaceutical Sciences, 8*(2), 292–300.

Bashir, A., Ibrar, K., Shumaila, B., & Sadiq, A. (2012). Chemical composition and antifungal, phytotoxic, brine shrimp cytotoxicity, insecticidal, and antibacterial activities of the essential oils of *Acacia modesta*. *Journal of Medicinal Plants Research, 6*(31), 4653–4659.

Beauchamp, G. K., Keast, R. S. J., Morel, D., Lin, J., Pika, J., Han, Q., Lee, C.-H., Smith, A. B., & Breslin, P. A. S. (2005). Phytochemistry: Ibuprofen-like activity in extra-virgin olive oil. *Nature, 437*, 45–46.

Cicerale, S., Lucas, L. J., & Keast, R. S. J. (2012). Antimicrobial, antioxidant, and anti-inflammatory phenolic activities in extra virgin olive oil. *Current Opinion in Biotechnology, 23*(2), 129–135.

Corona, G., Spencer, J., & Dessi, M. (2009). Extra virgin olive oil phenolics: Absorption, metabolism, and biological activities in the GI tract. *Toxicology and Industrial Health, 25*, 285–293.

Dell'Agli, M., Fagnani, R., Galli, G. V., Maschi, O., Gilardi, F., Bellosta, S., Crestani, M., Bosisio, E., De Fabiani, E., & Caruso, D. (2010). Olive oil phenols modulate the expression of metalloproteinase 9 in THP-1 cells by acting on nuclear factor-kB signaling. *Journal of Agricultural and Food Chemistry, 58*, 2246–2252.

Devi, J. A. I., & Muthu, A. K. (2014). Gas chromatography-mass spectrophotometry analysis of bioactive constituents in the ethanolic extract of *Saccharum spontaneum* Linn. *International Journal of Pharmacy and Pharmaceutical Science, 6*(2), 755–759.

Elnagar, A. Y., Sylvester, P. W., & El Sayed, K. A. (2011). (S)-Oleocanthal as a c-Met inhibitor for the control of

metastatic breast and prostate cancers. *Planta Medica, 77*, 1013–1019.

Gong, D., Geng, C., Jiang, L., Cao, J., Yoshimura, H., & Zhong, L. (2009). Effects of hydroxytyrosol-20 on carrageenan-induced acute inflammation and hyperalgesia in rats. *Phytotherapy Research, 23*, 646–650.

Iacono, A., Gómez, R., Sperry, J., Conde, J., Bianco, G., Meli, R., Gómez-Reino, J. J., Smith, A. B., & Gualillo, O. (2010). Effect of oleocanthal and its derivatives on inflammatory response induced by lipopolysaccharide in a murine chondrocyte cell line. *Arthritis & Rheumatism, 62*, 1675–1682.

Impellizzeri, D., Esposito, E., Mazzon, E., Paterniti, I., Di Paola, R., Bramanti, P., Morittu, V. M., Procopio, A., Britti, D., & Cuzzocrea, S. (2011). The effects of oleuropein aglycone, an olive oil compound, in a mouse model of carrageenan-induced pleurisy. *Clinical Nutrition, 30*, 533–540.

Katariya, L., Ramesh, P., & Borges, R. (2017). Dynamic environments of fungus-farming termite mounds exert growth-modulating effects on fungal crop parasites. *Environmental Microbiology, 20*(3), 971–979.

Khymenets, O., Fitó, M., Covas, M. I., Farré, M., Pujadas, M. A., Muñoz, D., Konstantinidou, V., & de la Torre, R. (2009). Mononuclear cell transcriptome response after sustained virgin olive oil consumption in humans: An exploratory nutrigenomics study. *OMICS: A Journal of Integrative Biology, 13*, 17–19.

Konstantinidou, V., Covas, M.-I., Muñoz-Aguayo, D., Khymenets, O., de la Torre, R., Sáez, G., Tormos, M. d. C., Toledo, E., Martí, A., & Ruiz-Gutiérrez, V. (2010). In vivo nutrigenomic effects of virgin olive oil polyphenols within the frame of the Mediterranean diet: A randomized controlled trial. *FASEB Journal, 24*, 2546–2557.

Krishnamoorty, K., & Paulsamy, S. (2014). Phytochemical profiling of leaf, stem, and tuber parts of *Solena amplexicaulis* (Lam.) Gandhi using GC-MS. *International Scholarly Research Notices*, 2014, 1–13.

Li, W., Sperry, J. B., Crowe, A., Trojanowski, J. Q., Smith, A. B., & Lee, V. M. Y. (2009). Inhibition of tau fibrillization by oleocanthal via reaction with the amino groups of tau. *Journal of Neurochemistry, 110*, 1339–1351.

Lima, L. A. R. S., Susana, J., Patricia, S. C., Lucia, P. S. P., & Maria, A. D. B. (2011). In vitro antifungal activity of fatty acid methyl esters of the seeds of *Annona cornifolia* A.St.-Hil. (Annonaceae) against pathogenic fungus *Paracoccidioides brasiliensis*. *Revista da Sociedade Brasileira de Medicina Tropical, 44*(6), 777–780.

Mahamat, O., André-Ledoux, N., Christopher, T., Mbifu, A., & Albert, K. (2018). Assessment of antimicrobial and immunomodulatory activities of termite associated fungi, *Termitomyces clypeatus* R. Heim (Lyophyllaceae, Basidiomycota). *Clinical Phytoscience, 4*(1), 28.

Mahamat, O., Christopher, T., Andre-Ledoux, N., Jude, A., Ndiane, N., & Albert, K. (2018). Screening of the immunomodulatory and antibacterial activity of *Termitomyces letestui* (Pat.) Heim (Lyophyllaceae), an edible mushroom from Cameroon. *Journal of Basic and Clinical Physiology and Pharmacology, 29*(6), 645–650.

Meneses, G., Rosetti, M., Espinosa, A., Florentino, A., Bautista, M., & Díaz, G. (2018). Recovery from an acute systemic and central LPS inflammation challenge is affected by mouse sex and genetic background. *PLOS ONE, 13*(8).

Nandika, D., Karlinasari, L., Arinana, A., Batubara, I., Sitanggang, P. S., & Santoso, D. (2021). Chemical components of fungus comb from Indo-Malayan termite *Macrotermes gilvus* Hagen mound and its bioactivity against wood-staining fungi. *Forests, 12*(11), 1591.

Njouonkou, A. L., Ekobo, S. A. B., Njayou, F. N., Raspé, O., Moundipa, P. F., & Degreef, J. (2020). Výskyt, využití a antioxidační potenciál *Termitomyces*

reticulatus v Kamerunu. *Czech Mycology, 72*(1), 19–32.

Omonike, O. O., Clarice, N. D., Ramsay, S. T. K., Toluwanimi, E. A., Abraham, N., & Jane, L. W. (2021). γ-Glutamyl-β-phenylethylamine, a novel α-glucosidase and α-amylase inhibitory compound from *Termitomyces robustus*, an edible Nigerian mushroom. *Natural Product Research, 8*, 1–11.

Oramahi, H. A., Diba, F., & Wahdina. (2011). Aktivitas antijamur asap cair dari serbuk gergaji kayu akasia (*Acacia mangium* Willd) dan kayu laban (*Vitex pubescens* Vahl). *Jurnal Ilmu-ilmu Hayati dan Fisik, 13*(1), 79–84.

Pitt, J., Roth, W., Lacor, P., Smith III, A. B., Blankenship, M., Velasco, P., De Felice, F., Breslin, P., & Klein, W. L. (2009). Alzheimer's-associated Aβ oligomers show altered structure, immunoreactivity and synaptotoxicity with low doses of oleocanthal. *Toxicology and Applied Pharmacology, 240*, 189–197.

Rawal, J. R., & Sonawani, P. R. (2016). Determination of bioactive components of *Cynodon dactylon* by GC-MS analysis & its in vitro antimicrobial. *International Journal of Pharmacy & Life Sciences, 7*(1), 4880–4885.

Sharma, R., Sharma, Y. P., Hashmi, S. A. J., Kumar, S., & Manhas, R. K. (2022). Ethnomycological study of wild edible and medicinal mushrooms in district Jammu, J&K (UT), India. *Journal of Ethnobiology and Ethnomedicine, 18*, 23.

Suryaningrum, T. D., Thamrin, W., & Hendy, K. (2006). Uji aktivitas senyawa antioksidan dari rumput laut *Halymenia harveyana* dan *Eucheuma cottonii*. *Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan, 1*(1), 51–64.

Velmurugan, N., Han, S. S., & Lee, Y. S. (2009). Antifungal activity of neutralized wood vinegar with water extracts of *Pinus densiflora* and *Quercus serrata* sawdust. *International Journal of Environmental Research, 3*(2), 167–176.

Witasari, L. D., Wahyu, K. W., Anugrahani, B. J., Kurniawan, D. C., Haryanto, A., & Nandika, D. (2022). Antimicrobial activities of fungus comb extracts isolated from Indomalayan termite (*Macrotermes gilvus* Hagen) mound. *AMB Express, 12*, 14.